Assessment of Diurnal Temporal Activity-Patterns of Mandarin Ducks (*Aix galericulata*) in a Wooded Wetland

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Declaration: *Data was collected by the author. Statistical analyses and write-up were conducted by the author, with guidance from all named supervisors.*

COVID-19 STATEMENT

COVID-19 pandemic had no effect on the development of this work, as data collection took place outdoors. Therefore, original research questions and methodologies were maintained throughout the year.

Birds of various species are housed in zoological collections all over the world and are some of the most common species in animal populations kept under human care. However, zoo-based research tends not to focus on birds. As a consequence, many suffer from an unsuitable environment which can contribute to poor welfare and conservation outcomes. Careful observations of how species live and behave in their natural habitats can provide us with a wealth of knowledge about their needs, desires, and internal states, which can then be used to enhance welfare, captive care and management. For this study, mandarin ducks (*Aix galericulata*) were chosen as a focal group since, like many species of waterfowl, they are widely kept in both private institutions and zoos, yet little attention has been paid to understanding their core needs in captivity. A wild free-living population of mandarin ducks living at Isabella Plantation in Richmond Park was used in this research. Firstly, data on state behaviours including resting, swimming, foraging, perching, preening and vigilance was collected on five days a week (8am-6pm) from the 26 March 2021 to 26 May 2021 to assess time-activity budgets. Secondly, sex, time of day, pond size, vegetation coverage, social period, weather, and visitor and bird number were recorded to assess whether any of these factors had an impact on the mandarin duck's time-budget. Lastly, these budgets were visually compared to those of captive pinioned mandarin ducks from Bruggers and Jackson's (1977) study, to assess whether activity levels and patterns differed between wild and pinioned captive birds. The main daily activity patterns of free-living wild mandarin ducks consisted of resting (19.88%), swimming (19.57%), foraging (19.47%), perching (13.43%), preening (12.98%) and vigilance (8.67%), with variations in these patterns related to all of the factors mentioned above. Results also show that diurnal activity levels are similar throughout the day and for both ponds and sex, but slightly differ for social period whereby ducks spent the most time being active during the Pre-Incubation period and the most time being inactive during the Incubation period. Furthermore, results show inconsistencies between the activity levels and patterns of these free-living wild mandarin ducks and those of pinioned captive mandarin ducks, suggesting that birds unable to fly clearly do not have the opportunity to express all of their natural behaviours. Lastly, with the help of camera traps, future research should try to include observations of nesting females as well as nocturnal time-activity budgets, rather than just focussing on diurnal behaviour patterns.

Key words: Mandarin duck, *Aix galericulata*, waterfowl, behaviour, Time-budget, Activity-patterns

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1.0 | INTRODUCTION

Animal welfare is a complex, ever- evolving concept that is influenced by cultural, economic, ethical and political concerns (Fraser, 2008; Green and Mellor, 2011; Hausberger et al., 2020; Lesimple, 2020; Lesimple et al., 2020; Ohl and van der Staay, 2012). Due to its complexity, assessing animal welfare requires objective, measurable, and clear evidence-based parameters (Broom, 1999; Hausberger et al., 2020; Lesimple, 2020; Lesimple et al., 2020, 2019; McGreevy et al., 2018; Wolfensohn, 2020). Evidence-based zoo management is founded on the idea that rather than relying on "traditional best practices" and ways that have merely "worked in the past," housing and husbandry standards should be assessed for their efficiency using data (Hosey et al., 2009; Melfi and Hosey, 2011; Melfi, 2009; Rose, 2018). Given that welfare is an individual and subjective experience (Dawkins, 2021), the scientific community has shifted away from resource-based indicators (i.e. does it have access to what it “probably” needs) toward more animal-based indicators, which assess not only the quality of an animals living environment, but also the animal's psychological and physical health and its ability to carry out a diversity of species-appropriate behaviours (Auer et al., 2021; Hausberger et al., 2020; Hosey et al., 2009; Maple, 2013; Rose, 2018; Waran and Randle, 2017; Wolfensohn, 2020). As a result, behaviour is increasingly being utilised as an indicator for animal wellbeing, as it can give significant information into an animal's subjective state (Dawkins, 2003, 1990, 2021; Hockenhull and Whay, 2014; Hughes and Duncan, 1988; Manning and Dawkins, 2012; Maple, 2013; Martins et al., 2012; Minero et al., 2016; Neave et al., 2021; Wolfensohn, 2020).

Maintaining natural behaviours in captive animals is not only vital to their wellbeing, but also to the success of conservation efforts (Kleiman et al., 2010). This is because phenotypic and genetic divergence between wild and captive populations may occur if captive animals are required to adapt to their artificial environment (Kleiman et al., 2010). Of course, not all wild behaviours will be, and need to be performed in captivity though (i.e. fleeing predators) (Waran and Young, 1996), but this is not at the expense of the individual’s quality of life (Rose, 2018). Those with underlining motivational needs however, behaviours that an animal must perform regardless of its environment, are the behaviours that must be considered (Dawkins, 1990; Manning and Dawkins, 2012; Rose, 2018).

One way to quantify behaviour is to watch an animal over an extended period and make a time-activity budget (Bridges and Noss, 2011). These budgets can help us understand how individuals interact with their environment as well as the amount of time they need to devote to the activities that are critical for their survival and reproduction (Bridges and Noss, 2011). Time-Activity budgets are commonly recognised as a valuable source of information for captive animal management. (Cooper and Jordan, 2013; Dawkins, 1989; Defler, 1995; Hosey et al., 2009; James Brereton, 2019; Rose, 2018). Wild time-activity budgets may be useful for establishing guidelines as well as displaying the types of behaviour shaped by natural selection (Stolba and Wood-Gush, 1984). They can also be used to examine whether the frequency of behaviours seen in captive animals is different from the that observed in wild animals (Cooper and Jordan, 2013; Dawkins, 1989; Melfi and Feistner, 2002; Rose et al., 2018).

Conflicting demands often have an impact on how individuals choose to allocate their time budget to different activities (Bartness and Albers, 2000; Ebensperger and Hurtado, 2005). As a result, not only must they allocate time to the activities that increase breeding and nutritional goals but also to the those that minimise risks and costs imposed by the environment (Alkon and Saltz, 1988; Ebensperger and Hurtado, 2005; Halle, 2000; Weiner, 2000). For example, multiple environmental factors including, time (Bruggers and Jackson, 1977; Heise et al., 2019; YiJin et al., 2019), water levels (Shao et al., 2018), prey density (Kloskowski et al., 2010), pond size (Sebastián-González and Green, 2014), season (Ali et al., 2016; Rose et al., 2018), social periods (Bruggers and Jackson, 1977), vegetation structure (Ali et al., 2016; Tassicker et al., 2006), weather (Bennett and Bolen, 1978; Elkins, 1983; Heise et al., 2019; Liechti, 2006; Zeng et al., 2013), human presence (Burger and Gochfeld, 1998; Price, 2008), and bird presence (Udvardy, 1951), and individual factors including, energy requirements, sex-specific breeding activity (Bruggers and Jackson, 1977; YiJin et al., 2019), have been known to affect the time budgets of birds whereby some of which have even resulted in activity trade-offs to individuals (Ebensperger and Hurtado, 2005). Thus, because an individual's activity budget varies in response to these many factors that influence acquisition, breeding success and survival, a better understanding of them may also aid in improved captive care (Ebensperger and Hurtado, 2005; Waran and Young, 1996).

Since the vast majority of zoo-based research focuses on just a few species, with a significant paucity of research on specific taxa, particularly all non-mammals (Melfi, 2009; Rose et al., 2019; Stoinski et al., 1998), this has created gaps in our ability to ensure adequate welfare within zoos (Melfi, 2009). This bias is also apparent in welfare-related studies. For example, a review shows a profound taxa bias, with the majority of research focusing on mammals (Azevedo et al., 2007). Therefore, our understanding of the welfare needs of many species is hampered by this bias toward mammals (Melfi, 2009). In fact, knowledge of the welfare needs for even some of the most widely kept non-mammalian species (i.e. waterfowl), is lacking (Rose and O'brien, 2020; Rose et al., 2019). Take the Mandarin duck (*Aix galericulata*) for example, due to its widespread aesthetic appeal, this species of duck has become one of the most popularly-kept of all waterfowl (McKinney, 1965). However, despite this, only a few behavioural studies have been carried out on this species (Bruggers and Jackson, 1977; YiJin et al., 2019), and a baseline for good mandarin duck welfare seems to be lacking.

Native to the Far East, the Mandarin Duck (*Aix galericulata*) is a perching duck species (Shurtleff and Savage, 1996) (Figure 1 & 2). Perching ducks are more arboreal than other waterfowl and thus prefer to spend much of their time perched high up in trees (Shurtleff and Savage, 1996). The mandarin duck is most active in the morning and late afternoon, but feeds day and night (Bruggers and Jackson, 1977; Shurtleff and Savage, 1996). Although the mandarin duck primarily feeds on aquatic plants and a variety of tree seeds, in the spring it also feeds on aquatic invertebrates (Shurtleff and Savage, 1996) since breeding ducks require a lot of protein (Holm and Scott, 1954; Kear, 2005; Krapu and Reinecke, 1992; Krapu and Swanson, 1975). Moreover, in the spring, hens have been found to feed for far longer periods of time than their mates (Bruggers and Jackson, 1977). While a mandarin duck pair will breed for several seasons in a row, they do not necessarily mate for life (Shurtleff and Savage, 1996). Nevertheless, they form strong seasonal pair bonds whereby drakes are very protective of their partner (Shurtleff and Savage, 1996), especially during the breeding season in spring (Bruggers and Jackson, 1977).

Figure 1. A Male Mandarin Duck ("Mandarin Duck Facts | Aix Galericulata - The RSPB," n.d.).

Figure 2. A Female Mandarin Duck ("Mandarin Duck Facts | Aix Galericulata - The RSPB," n.d.).

Clearly, little is known about the mandarin duck's wild behavioural ecology, as well as the individual and environmental factors that influence its behaviour, therefore for this study, three aims and seven hypotheses were formed (Table 1).

Table 1. The three aims and seven hypotheses for this study whereby the hypotheses were formed based on textbooks, previous publications within the literature and observations during the pilot study.

Number	Aims
1	Quantitively study the way in which free-living wild mandarin ducks allocate their time between their different activities in nature during spring.
2	Reveal the effects that sex, time of day, pond size, vegetation coverage, social period, weather, and visitor and bird number has on this species' time-activity budget.
3	Visually compare the time-activity budgets of wild free-living and captive mandarin ducks, to determine whether activity levels and the frequency of behaviours observed in captivity differs from that expressed in the wild to provide intitial data towards testing it in the future.
	Hypotheses
1	Average time perching would be higher than average time spent off the ground (i.e. flying).
2	Activity levels would be highest in the morning and evening.
3	Average time spent being active during spring would be higher than the average time spent being inactive.
4	Activity levels would be lowest during the Incubation period and thus resting behaviours would be highest during this time.
5	Hens would spend a significantly larger amount of time foraging compared to males, whereas drakes would spend a larger amount of time being vigilant than females.
6	Ducks would spend the largest amount of time foraging during the Pre-Incubation period.
7	Activity patterns are likely to be more diverse and activity levels are likely to be higher in wild birds than captive birds.

2.0 | MATERIALS AND METHODS

2.1 | STUDY AREA & POPULATION

In Richmond Park exists the Isabella Plantation (Figure 3 & 4), a 40 acre enclosed woodland area ("A Guide To Isabella Plantation," n.d.). Two ponds, home to a variety of birds, including an established population of approximately 35 breeding mandarin ducks (A. Ergun, personal communication, March 26, 2021) were selected for intensive observations. These included Peg's Pond, which, after deducting the area of its central island using "Google Maps" ("Google Maps," n.d.) distance and area calculator, has an area of open water of approximately 936m^2 (Figure 5 & 6) and Thomson's Pond, with an area of open water of approximately 439m^2 water (Figure 7).

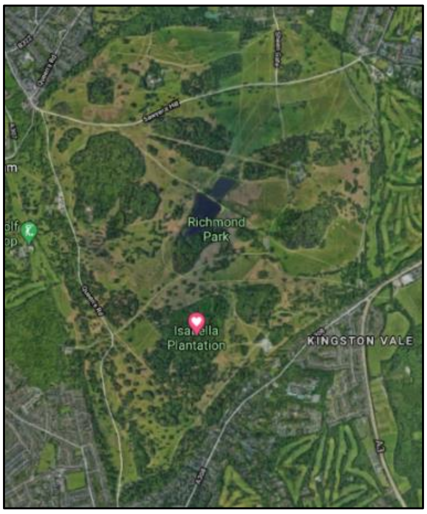

Figure 3. The satellite view of Richmond Park and Isabella plantation's location ("Map of Richmond Park - Richmond Park - The Royal Parks," n.d.).

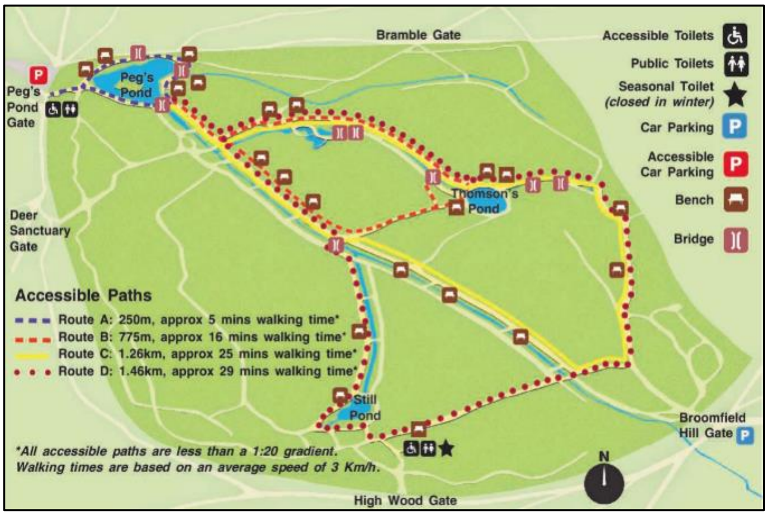

Figure 4. Map of Isabella Plantation showing the location of the two ponds, Peg's Pond and Thompson's Pond, where the Mandarin ducks can be found ("A Guide To Isabella Plantation," n.d., "Map of Richmond Park - Richmond Park - The Royal Parks," n.d.).

Figure 5. Google map view of Peg's pond showing the total distance and area of the entire pond in metres and feet ("Map of Richmond Park - Richmond Park - The Royal Parks," n.d.).

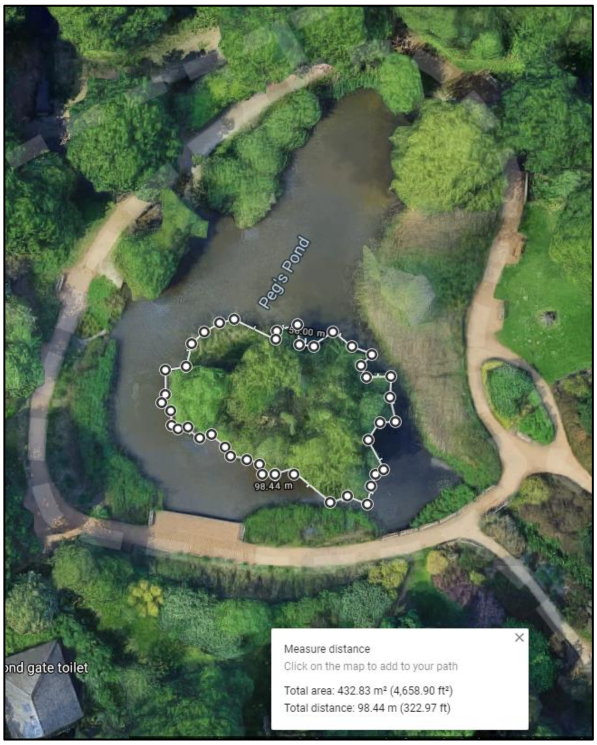

Figure 6. Google map view of Peg's pond showing the total distance and area of its central island in metres and feet ("Map of Richmond Park - Richmond Park - The Royal Parks," n.d.).

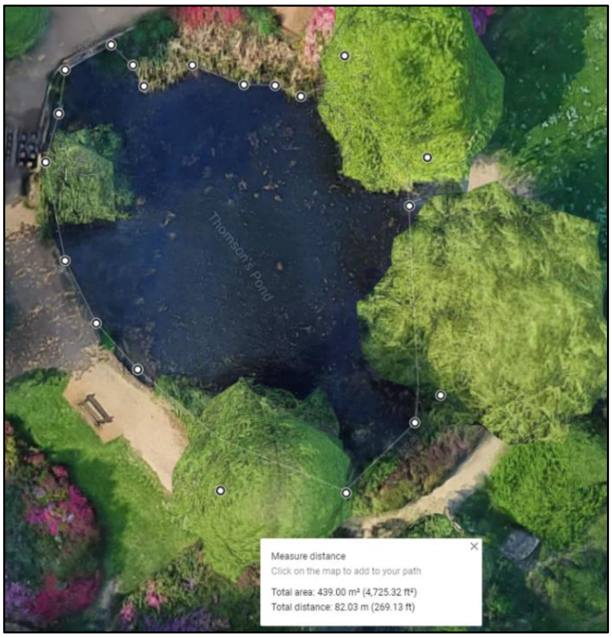

Figure 7. Google map view of Thomson's pond showing the total distance and area of the entire pond in metres and feet ("Map of Richmond Park - Richmond Park - The Royal Parks," n.d.).

2.2 | SAMPLING BIRD BEHAVIOUR

2.2.1 | AD LIBITUM SAMPLING

Quantitative recording of behaviour was preceded by a period of preliminary observation (3–6 March 2021, 8am–6 pm), aimed at minimising intra-observer variation and understanding and describing both the subjects and their behaviour. Intra-observer reliability was measured by filming a twenty-minute observation period alongside recording real-life observations, and then comparing the variation of results between the two. This was first assessed during the pilot study and then fortnightly whereby, the agreement for each assessment was 80% for pilot study and then 90%, 90%, 95%, 90%, and 95% for the entire observation period. Moreover, through these preliminary observations and other published ethograms (Downs et al., 2017; Shenglin Yang et al., 2016; YiJin et al., 2019), an ethogram was created (Table 2).

Table 2. Definitions of Various State and Event Behaviours of the Mandarin Duck During Spring. Behaviour patterns of fairly short duration (<5 seconds long), such as discrete body movements, were classified as "Events" and those of fairly long duration (>5 seconds long) as "States" (Martin and Bateson, 2007). Behaviours were also grouped into *active* and *inactive* states whereby *active* is characterised by the presence of motion.

Category	States	Description
	Out of Site	No longer visible
Active	**Natural Foraging**	Surface or diving feeding, catching or swallowing food or duck seeks out food (naturally) in and out of water
	Feeding by Visitor	Surface or diving feeding, catching or swallowing food or duck seeks out food (from visitors) in and out of water
	Preening	Any element of the preening sequence inluding nibbling feathers, head rolls and shaking, that occurs when duck is either in the water or on land
	Walking	Slow movement on the ground, out of the water
	Running	Rapid movement on the ground, out of the water
	Swimming	Rapid or Slow movement on the water with no foraging behaviour
	Courtship	Drake performs a drinking-preening-behind-the-wing sequence in the water / Hen nibbles the throat region of mate and utters coquette call. Hen flattens herself on the water in copulation posture, turning around and around
	Copulation	Drake is ontop of a hen mating in the water
	Vigilance	Duck is stood upright, motionless, alert and watchful, focusing on a particular alarming stimulus for a relatively long duration
	Flying	Flying for a relatively long duration, usually away from the study site
Inactive	**Resting**	Loaf or sleeping such as eyes are closed (or one eye is closed), neck is short, no head movements and/or or bill is tucked under wing on either water or land
	Perching	Loaf or sleeping such as eyes are closed (or one eye is closed), neck is short, no head movements and/or bill is tucked under wing in either a tree, on a branch or above ground
	Events	**Description**
	Vocalisation	Display call is like a thin, whistling and rapidly rising "hueessst, accompanied by deeper clappering sounds. Other sounds include a short and sharp, coot-like "ket", and a short "ack".
	Alert	Duck is attentive for a very brief moment during the performance of a state behaviour
	Fleeing	Duck is moving quickly away from another animal, usually in response to a threat or other aggressive behaviour
	Conspecific Social Interaction	Any brief interaction with another mandarin duck, including pecking, aggression or chasing
	Contraspecific Social Interaction	Any brief interaction with another species of bird, including pecking, aggression or chasing
	Flight	Any brief flight which usually occurs within the study site
	Maintenance	Mostly body fluffing, body shaking and wing flapping but also sometimes stretching, scratching, flapping, bathing, head dip in water

2.2.2 | DATA COLLECTION

Behavioural observations of wild free-living mandarin ducks were carried out during spring between 26 March 2021 to 26 May 2021, on five days a week (8am-6pm), whereby a total of 38 days of observations were made. Instantaneous sampling for a male and female pair was used to record mandarin duck *state behaviours* (Table 2). These behaviours were recorded at predetermined one-minute time intervals over a twenty-minute observation period. However, if both sexes were not present at any time or were not in a pair, one or two females or males were chosen instead. In conjunction to this, continuous event sampling was used to record *event behaviours* (Table 2) for those same individuals. To minimise selection bias, for every twenty-minute observation period, two new ducks were picked at random. This was achieved by waiting for five minutes, facing away from the pond, between each observation period. Moreover, to further minimise selection bias, and to reveal the effects of vegetation coverage on this species' time-activity budget, a dice was used to randomly select whether two ducks in open water, close to vegetation cover, or in a tree were going to be chosen. When needed, binoculars (8x42) were used to get a better view of the ducks. Keeping track of pairs was usually quite easy, since they typically stayed very close to one another and purposely distanced themselves from other mandarin ducks. Single females were also relatively easy to track. However, keeping track of two males was slightly more difficult since males, in the absence of females, tended to stay close to one another within large groups. Therefore, if at any point, a duck could no longer be tracked or seen, its behaviour was recorded as "*Out of Site*". Lastly, to reveal the effects that the time of day, pond size, vegetation coverage, social period, weather, and visitor and bird number had on this species' time-activity budget, five steps were conducted (Table 3).

Table 3. The four steps which were conducted in order to reveal the effects that multiple environmental factors had on the mandarin duck's time budget.

Step	Description
1	To reveal the effects of time of day on the mandarnis time-activity budget, twenty-minute observation periods were repeated four times for each time-period (i.e. morning, afternoon & evening), whereby the first twenty-minute observation period in the morning always started at 8.30am, the first in the afternoon at 1.00pm and the first in the evening at 4.00pm.
2	To reveal the effects of pond size on the mandarins time-activity budget, observations for each time-period alternated between the two study sites.
3	To reveal the effects of social period on time budget, observations and previous publications within the literature (Bruggers and Jackson, 1977 and Shurtless and Savage, 1996) were used to help determine different social periods during the breeding season. The entire observation period was thus split into three social periods whereby; 26 March-28 April was classified as the Pre-Incubation period, when male and female pairs were most abundant, 28 April-7 May was classified as the Incubation period, when very few female ducks were present, and lastly, 7 May-26 May was classified as the Post-Incubation period, when both females and ducklings were present.
3	To reveal the effects of visitor and bird number on the mandarins time-activity budget, visitor number, adult mandarin duck number and other waterfowl number whereby species included the Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), tufted duck (*Aythya fuligula*) and the common moorhen (*Gallinula chloropus*) were recorded at the start of every twenty-minute observation period.
4	To reveal the effects of weather on the mandarins time-activity budget, weather parameters including, weather description, temperature (cº), wind speed (mph), likelihood of precipitation (%), and humidity (%) were also recorded at the start of every 20-minute observation period to reveal their effects on time-budget. All weather data was recorded via BBC Weather iPhone application.

2.2.3 | CONSTRUCTING TIME-ACTIVITY BUDGETS

Descriptive statistics were performed in Excel Microsoft 375® and were used to describe the raw data whereby results are expressed as averages ± standard deviation (x%±SD). In the event that a focal animal could not be be observed for ≥ 60% of the time for any twenty-minute time-period, it was excluded from all descriptive and statistical analyses. To construct the activity-time budget of the mandarin duck during spring, the average percentage of time spent in each of the state behaviours was calculated. Similarily, an indivdual's average frequency of being involved in each of the event behaviours during spring was also calculated. Furthermore, the average activity levels of the mandarin duck during spring was calculated by determining the proportion of time that each indivudal was active and inactive. Lastly, time budgets, the average frequency of being involved in each of the event behaviours, and average activity levels were also calculated for both male and female mandarin ducks seperately for each time period, pond and social period.

2.2.4 | CONSTRUCTING A BEHAVIOUR-RHYTHM

A behaviour-rhythm of the mandarin duck for each social period was constructed to visually compare the activity patterns and levels of these wild ducks with pinioned captive ones from Brugger's and Jackson's study (Bruggers and Jackson, 1977).

2.2.5 | STATISTICAL ANALYSES

Statistical analyses were performed in IBM SPSS Statistics 26. Firstly, a Kolmogorov-Smirnov test was performed to examine whether the values collected for percentages of time spent on different behaviours fitted a normal distribution. However, a visual inspection of the histogram revealed otherwise. Therefore, the differences between average time spent being active and inactive as well as average time spent perching and off the ground, were tested using a Wilcoxon matched-pair signed-rank (2 samples) test. Secondly, Generalised Estimating Equations with a negative binomial log link function were used to analyse the effect of time of day on activity levels, social period on activity levels, resting and foraging rates, and sex on foraging and vigilance rates. Exchangeable working correlation matrix was used to account for the correlation between observation pairs. Each of the fixed effects (i.e. time of day, social period, pond size and sex) were evaluated individually first and those with p-value < 0.2 were further evaluated in multivariable models using a backward elimination approach. Post-hoc Pairwise Comparison was performed to compare the different categories within a significant fixed effect. Lastly, to provide additional information, the above was repeated to analyse the relationship between all of the response variables (i.e. the average percentage ducks engaged in each state behaviour and the frequency of occurrence for each event behaviour) and fixed effects (i.e. sex, study site, time of day, vegetation coverage, social period, public and bird number and weather parameters). However, multivariable analyses could not be performed on the behaviours the ducks performed very seldom (i.e. courtship, copulation, running and flight), due to the insufficient amount of data for them. Statistical results are expressed as medians ± interquartile range (x%+IQR) and rate ratios (RR) with 95% confidence intervals, with $p<0.05$ considered to be significant.

3.0 | RESULTS

3.1 | TIME BUDGET

701 out of 746 observations were analysed (females accounting for 230 of these, and males 471). The significantly lower total number of observed females compared to males is explained by the fact that only three females were seen at the ponds during the Incubation period. Resting, foraging (natural foraging and feeding by visitor), swimming, perching, preening and vigilance, were the main state behaviours of the mandarin ducks over the spring and breeding season (Table 4; Figure 8). Conversely, out of site, walking, courtship, copulation, running and flight were the state behaviours which occurred the least (Table 4; Figure 8) and have been therefore categorised as "Other" in all of the following

graphs. Vocalisation, fleeing, alertness, and contraspecific social interactions were the events which occurred the most frequently, whereas maintenance, flight and conspecific social interactions, were the events which occurred the least frequently (Table 4; Figure 9). Lastly, throughout the entire observation period, mandarin ducks spent more time perching (0%±15) than flying (0%±0; Z=-14.327, p=0.000;) and spent more time being active (25%±80) than inactive (5%±45; Z=-10.46, p=0.000).

Table 4. Average Time Budget (%), Frequency of Occurrence, and Activity Levels of the Mandarin duck during spring.

State Behaviour	Average % Time (+SD)
Resting	19.88±28.97
Swimming	19.57±19.43
Natural Foraging	16.51±24.27
Perching	13.43±24.95
Preening	12.98±19.00
Vigilance	8.67±15.62
Out of Site	3.35±10.03
Feeding by Visitor	2.96±8.22
Walking	1.27±4.21
Courtship	0.73±2.57
Copulation	0.37±1.30
Flying	0.20±1.04
Running	0.15±1.33

Event Behaviour	Frequency of Occurrence (+SD)
Vocalisation	0.00055±0.00104
Fleeing	0.00054±0.00087
Alert	0.00043±0.00081
Contraspecific Social Interaction	0.00042±0.00097
Maintenance	0.00030±0.00062
Flight	0.00023±0.00065
Conspecific Social Interaction	0.00021±0.00072

Activity Levels	Average % Time (+SD)
Active	63.37±96.96
Inactive	33.30±53.92
Out of Site	3.35±10.03

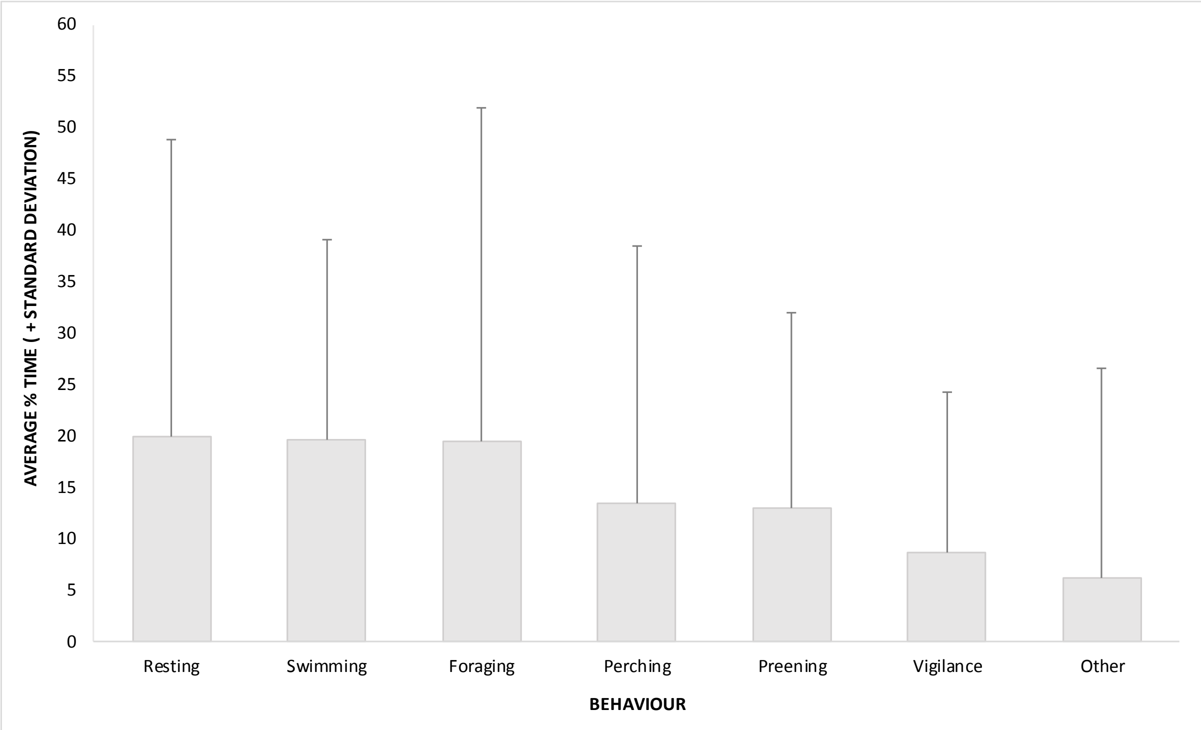

Figure 8. Average Time Budget (%) of the Mandarin duck during spring.

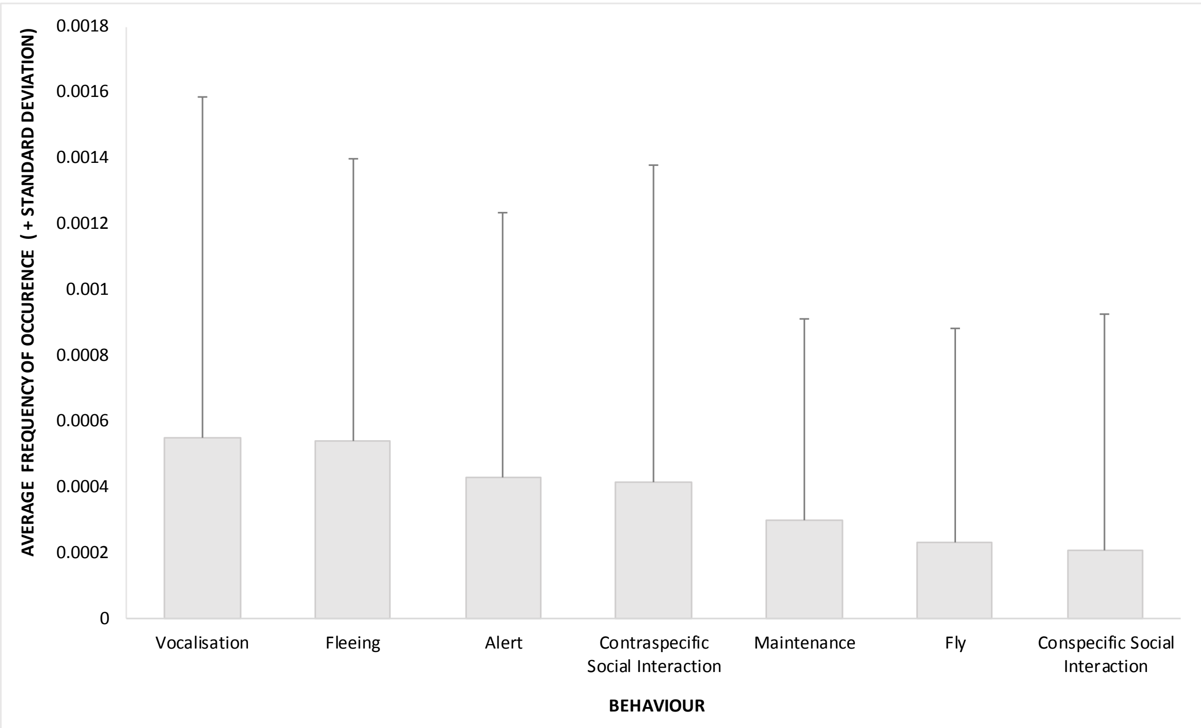

Figure 9. Average Frequency of Occurrence of the Mandarin duck during spring.

3.2 | SEX

As described above, females and males shared predominant state behaviours of resting, swimming, foraging, perching, preening and vigilance (Figure 10). In females, these behaviours accounted for 95.33%±140.14% of their total behaviours, and 93.32%±135.41% of the males. Moreover, although the main event behaviour of the male mandarin duck was vocalisation, the female's was fleeing (Figure

11). Females (20%±50) had a higher rate of natural foraging than males (0%±15; RR=3.53, 95%CI=2.88-4.34, p=0.000), and a lower rate of vigilance (0%±5) than males (0%±15; RR=0.08, 95%CI=0.46-0.13, p=0.000). Lastly, vocalisation occurred less frequently in females (0%±0) than males (0%±0.00084; RR=0.64, 95%CI=0.51-0.81, p=0.000).

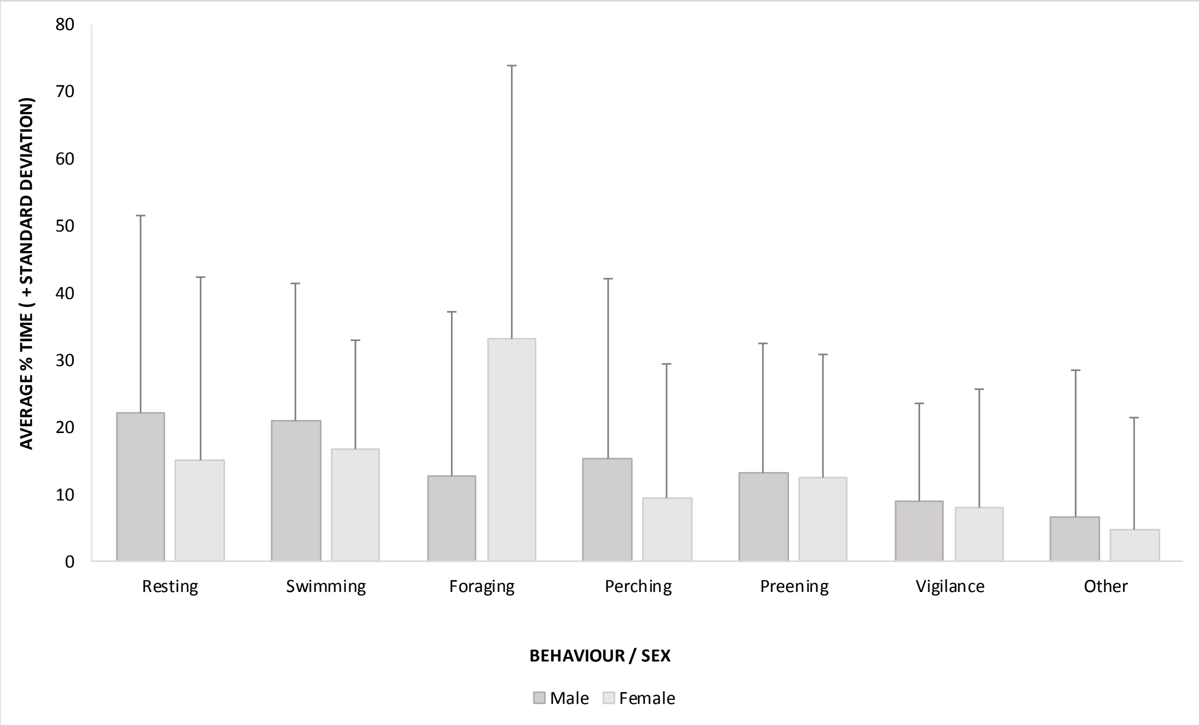

Figure 10. Average Time Budget (%) the Female and Male Mandarin duck during spring.

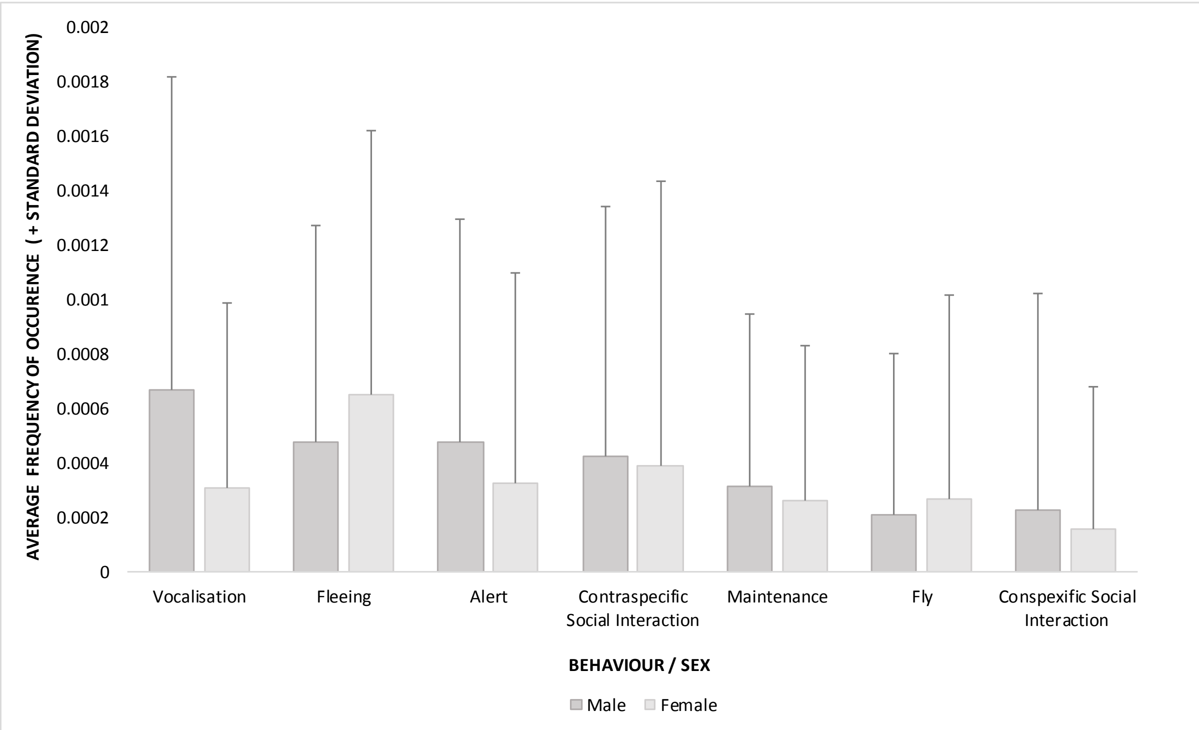

Figure 11. Average Frequency of Occurrence of the Female and Male Mandarin duck during spring.

3.3 | HABITAT VARIABLES

3.3.1 | TIME OF DAY

There was no significant difference in activity levels between time of the day (Morning: 25%±80; Afternoon:25%±85; Evening: 30%±80; p=0.436).

3.3.2 | POND SIZE

Throughout the entire observation period, a total of 379 and an average of 6 ducks were observed at Peg's Pond whereas a total of 322 and an average of 5 ducks were observed at Thomson's Pond. Ducks had a higher rate of swimming at Peg's Pond (15%±35) than Thomson's Pond (15%±20; RR=1.39, 95%CI=1.01-1.75, p=0.006).

3.3.3 | SOCIAL PERIOD

Although univariable analyses showed that ducks had higher rates of foraging during the Pre-Incubation period (7.5±30) than the Post-Incubation period (0%±20; RR=1.26, 95%CI=0.44-1.73, p=0.000), multivariable analyses showed the opposite whereby ducks had lower rates of forgaing during the Pre-Incubation period than the Post-Incubation period (RR=0.54, 95%CI=0.35-0.84, p=0.006). Further analyses, performed to explore this change in direction, showed that *Sex* and *Social Period* were confounded and showed that although females had higher foraging rates during the Pre-Incubation period (30%±55) than the Post-Incubation period (0%±15, RR=2.54, 95%CI=1.65-3.91, p=0.000), for males this was the opposite whereby they had lower rates of natural foraging during the Pre-Incubation period (5%±15) than the Post-Incubation period (0%±23.75, RR=0.66, 95%CI=0.45-0.95, p=0.019). The same analyses also showed that females had higher foraging rates during the Incubation period (50%±60) compared to both the Pre-incubation (RR=1.76, 95%CI=1.21-2.56, p=0.034) and Post-incubation period (RR=4.49, 95%CI=2.62-7.68, p=0.000). On the other hand, however, all analyses showed that ducks had a signifcantly higher rate of natural foraging during the Pre-Incubation period than the Incubation period (0%±10; RR=2.09, 95%CI=1.29-3.38, p=0.003).

Analyses also showed that ducks had higher rates of resting during the Incubation period (20%±40) than both the Pre-Incubation period (5%±25, RR=1.40, 95%CI=1.01-1.85, p=0.019) and Post-Incubation period (0%±25, RR=1.58, 95%CI=1.14-2.19, p=0.006). Lastly, ducks spent the most time being active during the Pre-Incubation period (27.5%±80) than both the Incubation (20%±65.5, RR=1.40, 95%CI=1.17-1.67, p=0.000) and Post-Incubation period (25%±95, RR=1.30, 95%CI=1.05-1.60, p=0.02) and the most time being inactive during the Incubation period (25%±65) than both the Pre-Incubation (5%±35; RR=1.51, 95%CI=1.21-1.89, p=0.000) and Post-Incubation period (0%±36.25; RR=1.65, 95%CI=1.26-2.16, p=0.000).

3.3.4 | VEGETATION COVERAGE

Since only five ducks were observed in a tree throughout the entire observation period, these observations were removed from analyses. Ducks in open water (0%±15) had a higher rate of vigilance than those close to vegetation cover (0%±5; RR=1.82, 95%CI=11.41-2.34, p=0.000). Conversely. ducks in open water (0%±20) had a lower rate of resting than those near vegetation cover (15%±60, RR=0.48, 95%CI=0.37-0.62, p=0.000). Lastly, ducks spent more time being active when in open water (35%±95) than when near vegetation cover (10%±47.5; RR=1.96, 95CI=1.66-2.30, p=0.000).

3.4 | WEATHER PARAMETERS

Throughout the entire observation period, five types of weather were described including sunny, sunny intervals, light cloud, thick cloud, light rain and heavy rain whereby sunny intervals and light cloud were the most common. Ducks had a lower rate of natural foraging (0%±0) and swimming (0%±7.5) in the heavy rain than in all other weather types (Table 6 & 7).

Table 6. Multivariable Statistical Results for Weather & Natural Foraging, Whereby Heavy Rain is Compared to all Other Types of Weather.

				95% Walk Confidence Interval for Difference	
Weather	**Median ± IQR**	**P-Value**	**RR**	**Lower**	**Upper**
Light Cloud	**5%± 25**	0.016	0.10	0.02	0.65
Light Rain	**0%± 15**	0.023	0.10	0.02	0.72
Sunny	**5%± 29**	0.025	0.11	0.02	0.76
Sunny Intervals	**5%± 30**	0.008	0.08	0.02	0.51
Thick Cloud	**5%± 36**	0.032	0.09	0.01	0.81

Table 7. Multivariable Statistical Results for Weather & Swimming, Whereby Heavy Rain is Compared to all Other Types of Weather.

				95% Walk Confidence Interval for Difference	
Weather	**Median ± IQR**	**P-Value**	**RR**	**Lower**	**Upper**
Light Cloud	**15%± 30**	0.000	0.21	0.09	0.50
Light Rain	**15%± 40**	0.000	0.16	0.07	0.39
Sunny	**15%± 20**	0.000	0.18	0.08	0.44
Sunny Intervals	**15%± 20**	0.000	0.21	0.09	0.50
Thick Cloud	**15%± 26**	0.010	0.25	0.09	0.72

On the other hand, however, ducks had a significantly higher rate of alertness in the heavy rain (0.001667±0.002083) than in light cloud (0±0.000833; RR=2.76, 95%CI=1.09-7.03, p=0.033), and sunny intervals (0±0; RR=3.59, 95%CI=1.42-9.08, p=0.007). They also had a higher rate of alertness in the light rain (0±0.000833) than in sunny intervals (0±0; RR=1.69, 95%CI=1.04-2.76, p=0.036).

While Temperature only had a significant effect on swimming (RR=0.97, 95%CI=0.93-1, p=0.048), likelihood of precipitation only had a significant effect on maintenance (RR=1.01, 95 CI=1-1.01, p=0.001). However, Wind Speed had a significant effect on both fleeing (RR=1.01, 95%CI=1.01-1.10, p=0.015) and flight (RR=0.90, 95%CI=0.84±0.97, p=0.000). Lastly, Humidity did not seem to have a significant effect on any behaviour.

3.5 | VISITOR AND DUCK NUMBER

Visitor number had a significant effect on feeding-by-visitor (RR=1.13, 95%CI=1.08-1.18, p=0.000). **A**dult mandarin duck number had a significant effect on natural foraging (RR=1.11, 95%CI=1.02-1.21, p=0.016). The same was true for other waterfowl number (RR=0.93, 95%CI=0.90-0.97, p=0.000).

3.6 | WILD FREE-LIVING VERSUS PINIONED DUCKS

To facilitate the comparison between the behaviour-rhythm of wild mandarin ducks from this study (Figure 12) and captive mandarin ducks from Brugger's and Jackson's paper (Figure 13) (Bruggers and Jackson, 1977), resting and perching were combined as "loafing". Although the activity patterns and levels in pinioned captive ducks during the Pre-Laying and Laying periods (Bruggers and Jackson, 1977) appear to be similar to those in wild ducks, they differ for the Post-Incubation period whereby the amount of time pinioned captive ducks spent foraging during this period appears to be notably less than that of wild ducks (Bruggers and Jackson, 1977). On the contrary, pinioned captive ducks appear to spend more time loafing during the Post-Incubation period than wild ducks (Bruggers and Jackson, 1977). In fact pinioned captive ducks appear to spend a lot more time loafing around after the Post-Incubation period (Bruggers and Jackson, 1977).

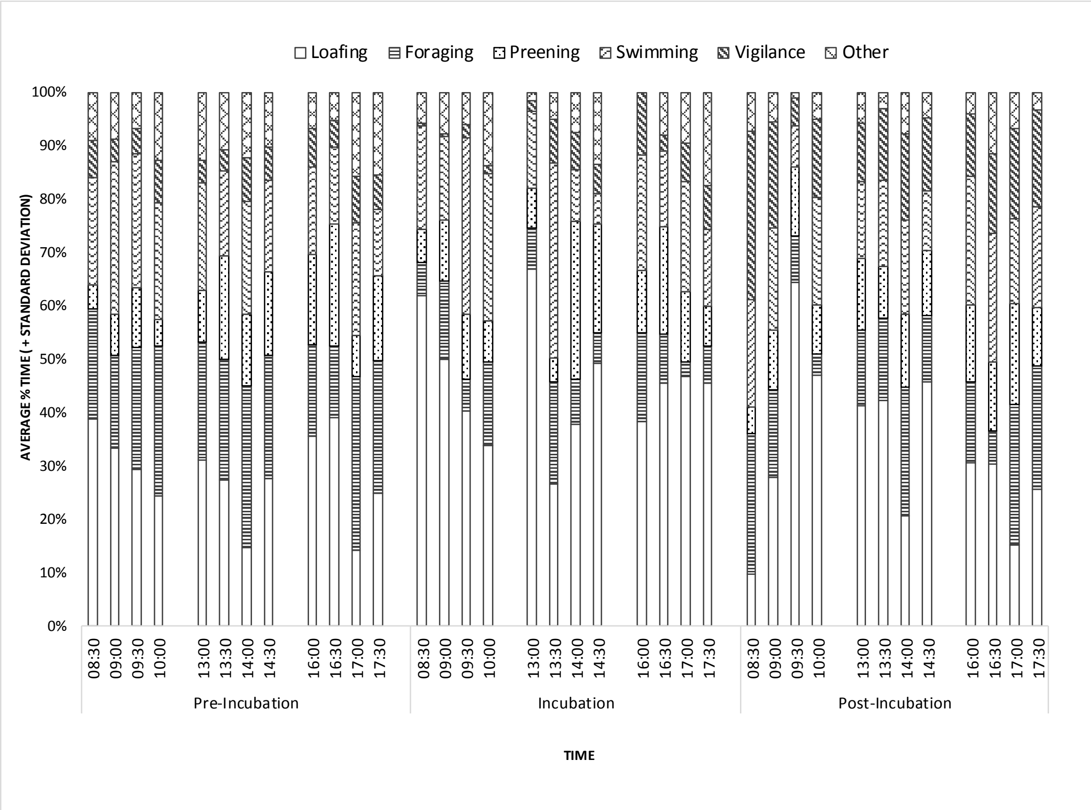

Figure 12. The Behaviour Rhythm of the Mandarin Duck During Different Social Periods.

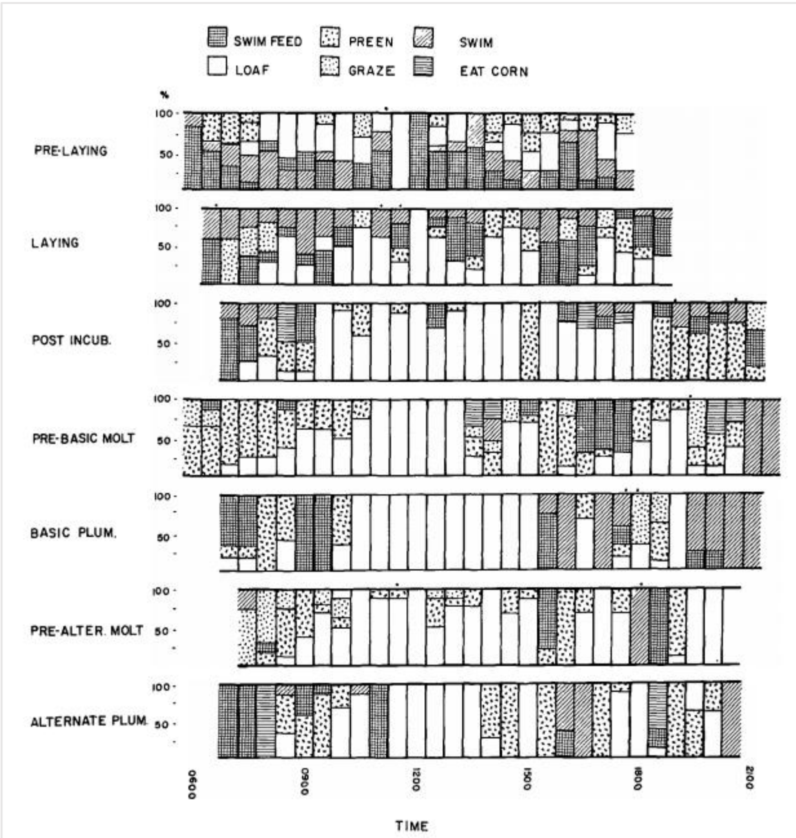

Figure 13. The Behaviour Rhythm of the Pinioned Captive Mandarin Duck During Different Social Periods (Bruggers and Jackson, 1977).

4.0 | DISCUSSION

The main daily activity patterns of free-living wild mandarin ducks consisted of resting, foraging, swimming perching, preening and vigilance, with variations in these patterns related to sex, time of day, pond size, vegetation coverage, social period, weather and visitor and bird number, which will be discussed in more detail below. Resting, swimming and foraging made up the highest proportion of the time-budget. As hypothesised, ducks were significantly more active than inactive throughout the entire observation period (i.e. spring). Moreover, mandarin ducks during spring appear to spend a higher proportion of their time being active (63.37%) than those during the wintering period (58.21%) (YiJin et al., 2019). The high levels of foraging and activity observed during this season appear to reflect seasonal changes in food availability, with reproduction in birds often timed to coincide with maximum food availability for nesting adults or developing young (Krapu and Reinecke, 1992). As hypothesised, mandarin ducks spent significantly more time perching than off the ground most likely because, as already mentioned, they prefer to spend much of their time perched high in trees (Shurtleff and Savage, 1996). This is especially true for drakes during the breeding season, since they like to perch close to their nesting hen as they devotedly guard them during the month-long incubation period (Davies and Baggott, 1989; Johnsgard, 1978; Lever, 2013; Shurtleff and Savage, 1996).

As predicted, mandarin ducks showed a significant sexual difference in terms of time used for foraging and vigilance. Captive mandarin ducks and other anatids have shown similar sexual differences during the breeding season (Arzel and Elmberg, 2014; Ashcroft, 1976; Bruggers and Jackson, 1977; Dwyer, 1974; Milne, 1974; Seymour and Titman, 1978; Smith, 1968; Sorenson and Derrickson, 1994; Stewart and Titman, 1980; Swanson et al., 1974). Differential energy costs of reproduction appear to be the cause of these variations in foraging rates. This is because egg production in Anseriformes is relatively costly in calories (King, 1973; Ricklefs, 1974), and thus breeding ducks need a high proportion of protein, usually in the form of aquatic invertebrates (Holm and Scott, 1954; Kear, 2005; Krapu and Reinecke, 1992; Krapu and Swanson, 1975). Sexual differences in vigilance rates, however, emphasise the importance of attendant males in protecting female foraging from other males and predators (Christensen, 2000). This would also explain why vocalisation occurred more frequently in males, since although generally rather silent (Kear, 2005; Shimba, 2019), mandarin drakes will be vocal in attempt to ward off threats, warn nearby intruders and/or signal nearby danger (Shurtleff and Savage, 1996).

Although it was hypothesised that activity patterns would be highest in the morning and evening, results suggested otherwise, as time of day did not significantly affect activity levels. According to multiple textbooks and previous publications within the literature however, mandarin ducks are most active in the early morning and in the evening (Kear, 2005; Shurtleff and Savage, 1996). However, unlike this study, they do not specifically look at one season alone. Therefore, the results from this study could suggest that, because spring is such a busy time of year for these animals, mandarin ducks need to spend as much time as they can being active throughout the day rather than just at certain times of the day. In fact, Bruggers and Jackson's (1977) report show that during Pre-Laying and Laying periods, mandarin hens were active throughout the day, but extended their mid-day inattentive period during the summer and fall (Bruggers and Jackson, 1977). However, these results could also suggest that observations were not carried out early enough in the mornings and late enough in the evenings to notice clear differences in the activity levels between the different times of the day. Therefore, future research should try to include earlier and later time-activity budgets and should, in fact, also try to include nocturnal time-activity budgets since several authors have noticed that mandarin ducks feed during the day and night (Bruggers and Jackson, 1977; Shurtleff and Savage, 1996), and thus exhibit nocturnal behavioural performance.

Swimming rates were higher at Peg's Pond compared to Thomson's Pond most likely because larger ponds have larger surface areas requiring ducks to swim further distances for longer periods of time to get to their destinations. Moreover, throughout the entire observation period, the average and total number of adult mandarin ducks present at Peg's Pond was higher than that of Thomson's Pond, implying that mandarin ducks prefer Peg's Pond. This could be due to several reasons, with the most obvious one being that larger areas can support more species because resource sources are more plentiful (Oertli et al., 2002; Sebastián-González and Green, 2014; Semlitsch et al., 2015). Another reason could be because Peg's Pond is surrounded by a littoral vegetation of reeds and sedges which is the mandarins preferred shelter choice (Shurtleff and Savage, 1996). Moreover, it could also be because, in the middle of Peg's Pond, there is an island where mandarin ducks appeared to frequently loaf. This is most likely because they are shy birds (Shurtleff and Savage, 1996), and thus felt safer loafing on an island surrounded by water, vegetation and trees. In fact, the results of this study support this since they showed that, ducks closer to vegetation cover had higher resting and lower vigilance rates as well as lower activity levels than those in open water.

Although it was hypothesised that ducks would spend the largest amount of time foraging during the Pre-Incubation period, due to confounding variables, results suggested otherwise. Moreover, although females had the highest foraging rates during the Incubation period, due to the very small number of observed females during this period, no valid inferences could be drawn about differences in proportion of time spent foraging during this period compared to others. Female mandarin ducks only leave their nests to feed early in the morning or late in the evening (Shurtleff and Savage, 1996), which would explain why such a small number of females were observed at the pond during the day throughout the entire Incubation period. It is therefore important that future studies also try to include observations of incubating females since this would increase the accuracy of the female's time-activity budget. Nevertheless, the sexual differences in foraging rates between the Pre-Incubation and Post-Incubation periods as well as the higher rates of foraging during the Pre-Incubation period than the Incubation period, supports the observations of other authors that, breeding females require high protein diets and thus consume a much greater proportion of aquatic invertebrates before egg laying (Bruggers and Jackson, 1977; Holm and Scott, 1954; Swanson and Nelson, 1970). The higher activity levels during the Pre-Incubation period than the Incubation period reflects the importance of ducks having to remain active in order to maximise nutrient intake in preparation for reproduction. On the contrary, as predicted, activity levels were lowest and resting rates were highest during the Incubation period, most evidently because males were guarding their incubating females. In fact, similar findings in resting rates have been reported for the same social period (Bruggers and Jackson, 1977).

Birds exhibited lower natural foraging and swimming rates in heavy rain than in all other types of weather, most likely because they were seeking shelter. However, ducks, are said to have perfected water repellency (Rijke, 1970) and thus seeking cover solely because of the rain would be counterproductive. Periods of heavy rain were also associated with relatively strong winds, with average wind speeds of 38.29mph. Since the onset of severe weather, particularly when accompanied by high wind velocities, can cause heightened stress levels in ducks (Bennett and Bolen, 1978), the results of this study could thus indicate that the mandarin ducks were seeking refuge to avoid "stormy weather". In fact, this would explain why alertness occurred more frequently in heavy and light rain than in other types of weather, and why there was a significant effect of wind speed on fleeing behaviour, whereby for every 1mph increase in wind speed, there was a 1% increase in the occurrence of fleeing.

Increased swimming rates in relation to falling temperatures is consistent with other publications within the literature (Finney et al., 1999; YiJin et al., 2019; Zeng et al., 2013), whereby for every 1 degree (Cº) increase in temperature, there was a 3% decrease in the rate of swimming. Birds have evolved multiple regulating mechanisms to cope with cold conditions. While some birds, like many endotherms, increase their metabolic rate in cold conditions to maintain body temperature (Coopers and Swanson, 1994; Dawson et al., 1983; Liknes et al., 2002; Qian and Xu, 1986; Tattersall et al., 2016, 2012), others reduce their activity to cut down on their energy consumption and heat loss (Siegfried, 1974; Sun et al., 2006; Verbeek, 1964). Therefore, the results of this study reveal that mandarin ducks maintained high metabolic rates even during adverse conditions.

Precipitation had a significant effect on maintenance whereby maintenance rates were higher during rainier periods since for every 1% increase in precipitation, there was a 1% increase in maintenance rates. Birds have evolved remarkably well to weather storms fluffing up their feathers in mild showers to keep warm while sleeking their feathers in heavy rain to make them more water-resistant (Kennedy, 1970). Birds are also known to flap their wings to remove adhering water drops from their feathers (McKinney, 1965). Therefore, results suggest that mandarin ducks were increasing maintenance rates for these very reasons.

Although it is a well-known fact that visitors can have a negative impact on an animal's behaviour and thus welfare, for instance, behaviours such as avoidance (Birke, 2002; Learmonth et al., 2018; Sellinger and Ha, 2005; Sherwen et al., 2015b), vigilance (Clark et al., 2012; Sherwen et al., 2015a) and aggression (Bortolini and Bicca-Marques, 2011; Glatston et al., 1984; Mitchell et al., 1991) have been observed in many zoo animals, including birds (Burger and Gochfeld, 1998; Price, 2008), visitor number surprisingly did not seem to have a significant impact on any vigilance, alert or fleeing behaviour. This may indicate that the mandarin ducks in Isabella Plantation have simply become used to the presence of people, as has been recorded in other birds (de Azevedo et al., 2012; Samia et al., 2015). This habituation is most likely due to the visitors feeding the ducks on a regular basis. In fact, the results of this study support this since visitor number had a significant impact on feeding-by-visitor rates, whereby, for every increase in visitor number, there was a 13% increase in feeding-by-visitor rates. However, frequent feeding and thus accustoming ducks to handouts, may lead to serious problems such as ducks relying on food from unnatural sources (Murray et al., 2016). As a result, natural behaviours like the need to forage for more varied and healthier food as well as the loss of their innate fear of people and other predators, which allows them to survive and reproduce, may be lost (Murray et al., 2016).

Adult Mandarin duck number had a significant effect on natural foraging and vigilance rates, whereby for every individual increase in mandarin duck number, there was a 11% increase in natural foraging rates, a 10% increase in vigilance rates and a 29% increase in the frequency of contraspecific social interactions. Social Facilitation, i.e. “when the performance of an animal’s behaviour increases the likelihood of other animals adopting the same behaviour, or intensifying it” (Bond, 2001), has been observed in a number of bird species (Clayton, 1976; Liste et al., 2014; Palestis and Burger, 1998; Rajecki et al., 1976), including mandarin ducks when preening (Bruggers and Jackson, 1977), and could explain why foraging rates increased when mandarin duck numbers did. In fact, highly sociable animals are more likely to exhibit social facilitated behaviour, which is thought to optimise resource exploitation and protection from predators (Clayton, 1978). Therefore, because mandarin ducks are both highly sociable and shy birds (Shurtleff and Savage, 1996), it makes sense that they would prefer to forage in groups, not just to maximise resource exploitation, but to feel safer from predators. Waterfowl number however, had an opposite effect on natural foraging whereby for every individual increase in other waterfowl number, there was a 7% decrease in foraging rates, presumably due to mandarin ducks wanting to avoid unnecessary conflicts with other species, especially during such a demanding time of the year.

The comparison made between the behaviour rhythm of wild and captive mandarin ducks (Bruggers and Jackson, 1977), do indeed suggest that activity patterns are likely to be more diverse in wild birds and that activity levels are likely to be higher in wild birds than captive birds. The lower levels of foraging in captive ducks might be explained by the confined setting, in which food is usually given on a regular basis, causing ducks to meet their daily energy requirements more rapidly than they would in the wild. Higher levels of inactivity in captive mandarin ducks may therefore be explained by this too. However, higher levels of inactivity could also be a result of pinioning. This is because flight in birds is important for physical activity and many species fly hundreds of miles every day for a number of reasons (Johnsgard, 1965). In fact, birds in captivity are often deprived of this natural skill due to improvised environments that do not provide sufficient living space or wing pinioning/amputation (Jen-Lung Peng et al., 2013).

5.0 | CONCLUSION

Not only did this study reveal how much time mandarin ducks devoted to activities like resting, foraging and staying vigilant in order to maximise their survival and reproduction, but also how their time-activity budgets were strongly influenced by numerous individual and environmental factors. It also revealed that activity patterns appear to be more diverse and activity levels appear to be higher in birds that can fly. Therefore, to conclude, it is evident that wild time-activity budgets, as well as the factors that influence their behaviour must be considered (i.e. providing appropriate food, especially during the breeding season, shelter for times of stormy weather, perches and vegetation cover for comfort, appropriate nesting boxes, a sufficient area of water for swimming and exercise, in a large enough social group) in order to manage captive mandarin ducks in a way that ensures their wellbeing will be good, if not great. Moreover, any restriction on the ability of birds to exercise in a species-specific manner such as flight, should clearly strongly be questioned. Finally, with the help of camera traps, future research should try to include observations of nesting females as well as a 24-hour time-activity budget, owing to both the limited number of females observed during the Incubation period and the fact that ducks were only watched during the day.

6.0 | CONFLICT OF INTEREST

None.

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9.0 | SUPPLEMENTARY MATERIAL

Table 8. Average Time Budget (%) of the Mandarin Duck at Different Times of The Day, at Both Study Sites, for Both Types of Vegetation Coverages and for Different Social Periods.

	TIME OF DAY			STUDY SITE		SEASON			VEGETATION COVERAGE	
Behaviour	Morning Average % Time (+SD)	Afternoon Average % Time (+SD)	Evening Average % Time (+SD)	Peg's Pond Average % Time (+SD)	Thomson's Pond Average % Time (+SD)	Pre-Laying Season Average % Time (+SD)	Nesting Season Average % Time (+SD)	Offspring Season Average % Time (+SD)	Open Water (+SD)	Near Vegetation Cover (+SD)
Out of Site	2.3±8.04	3.49±10.35	4.26±11.32	3.57±10.23	3.1±9.79	2.79±9.63	5.14±12.64	3.45±10.16	3.55±10.23	2.99±9.66
Natural Foraging	15.56±23.26	17.42±23.77	16.6±25.78	13.4±21.87	20.24±26.37	19.54±25.3	8.2±15.86	15.3±24.88	20.76±25.91	7.63±17.38
Human Foraging	3±7.81	3.32±9.48	2.56±7.12	3.83±9.81	1.95±5.66	4.54±10.11	1.76±5.92	0.55±2.59	3.92±9.53	0.95±3.70
Preening	8.51±12.41	14.9±21.43	15.44±20.82	10.97±17.17	15.39±20.71	13.04±19.93	13.92±19.87	12.4±16.41	12.95±18.22	13.21±20.64
Walking	1.52±4.86	1.19±3.40	1.1±4.30	0.6±2.30	2.05±5.59	1.84±5.20	1.13±3.41	0.23±1.04	1.51±4.73	0.77±2.78
Swimming	22.82±22.26	17.77±17.29	18.32±18.18	21.98±21.62	16.79±16.05	20.52±19.63	19.91±19.77	17.63±18.67	23.17±19.38	11.98±17.1
Courtship	0.75±2.92	0.66±1.92	0.79±2.82	0.56±1.95	0.94±3.14	0.94±3.05	0.28±1.14	0.58±2.02	0.89±2.87	0.41±1.79
Copulation	0.25±1.08	0.37±1.31	0.49±1.48	0.44±1.41	0.28±1.15	0.5±1.5	0±0	0.3±1.19	0.46±1.44	0.18±0.93
Vigilance	8±15.54	8.2±15.79	9.85±15.5	10.66±17.21	6.36±13.15	6.53±12.41	4.46±9.07	15.23±21.15	10.68±17.08	4.56±11
Running	0.29±2.11	0.11±0.85	0.05±0.47	0.11±0.81	0.19±1.76	0.16±1.60	0±0	0.2±1.10	0.22±1.62	0±0
Flight	0.12±0.74	0.21±1.09	0.27±1.21	0.12±0.85	0.28±1.22	0.18±1.06	0.05±0.48	0.3±1.19	0.21±1.04	0.18±1.05
Resting	22.78±30.78	18.1±28.59	18.59±26.86	20.86±30.98	18.47±26.02	18.36±27.88	26.58±30	18.7±29.44	14.42±22.44	31.91±36.79
Perching	14.17±25.69	14.31±26.56	11.75±22.28	12.96±24.91	14.03±25.02	11.11±20.59	18.61±28.59	15.15±29.57	7.33±16.77	25.3±33.17

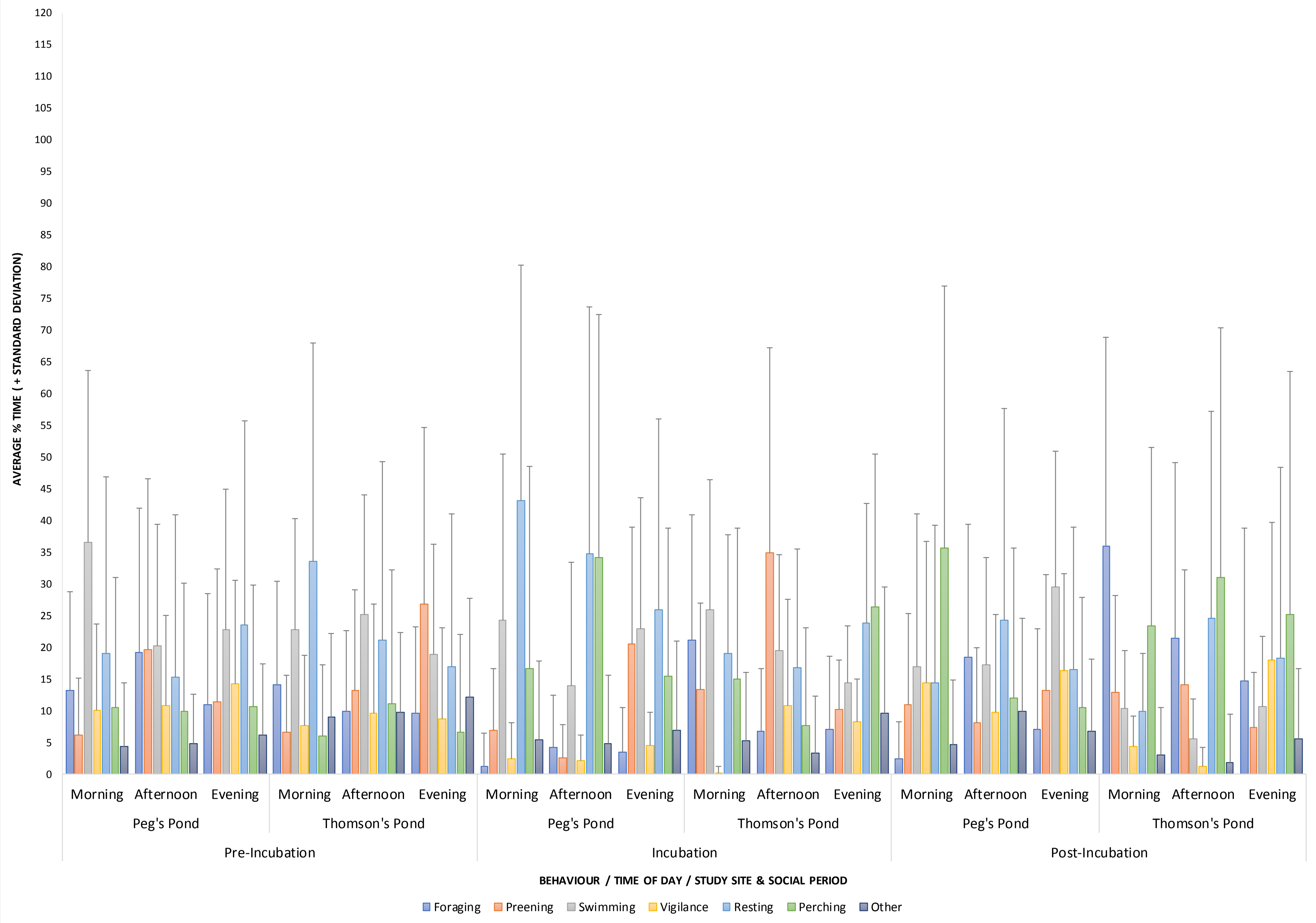

Figure 14. Average Time Budget (%) of the Male Mandarin Duck at Different Times of The Day, at Both Study Sites and During Different Social Periods.

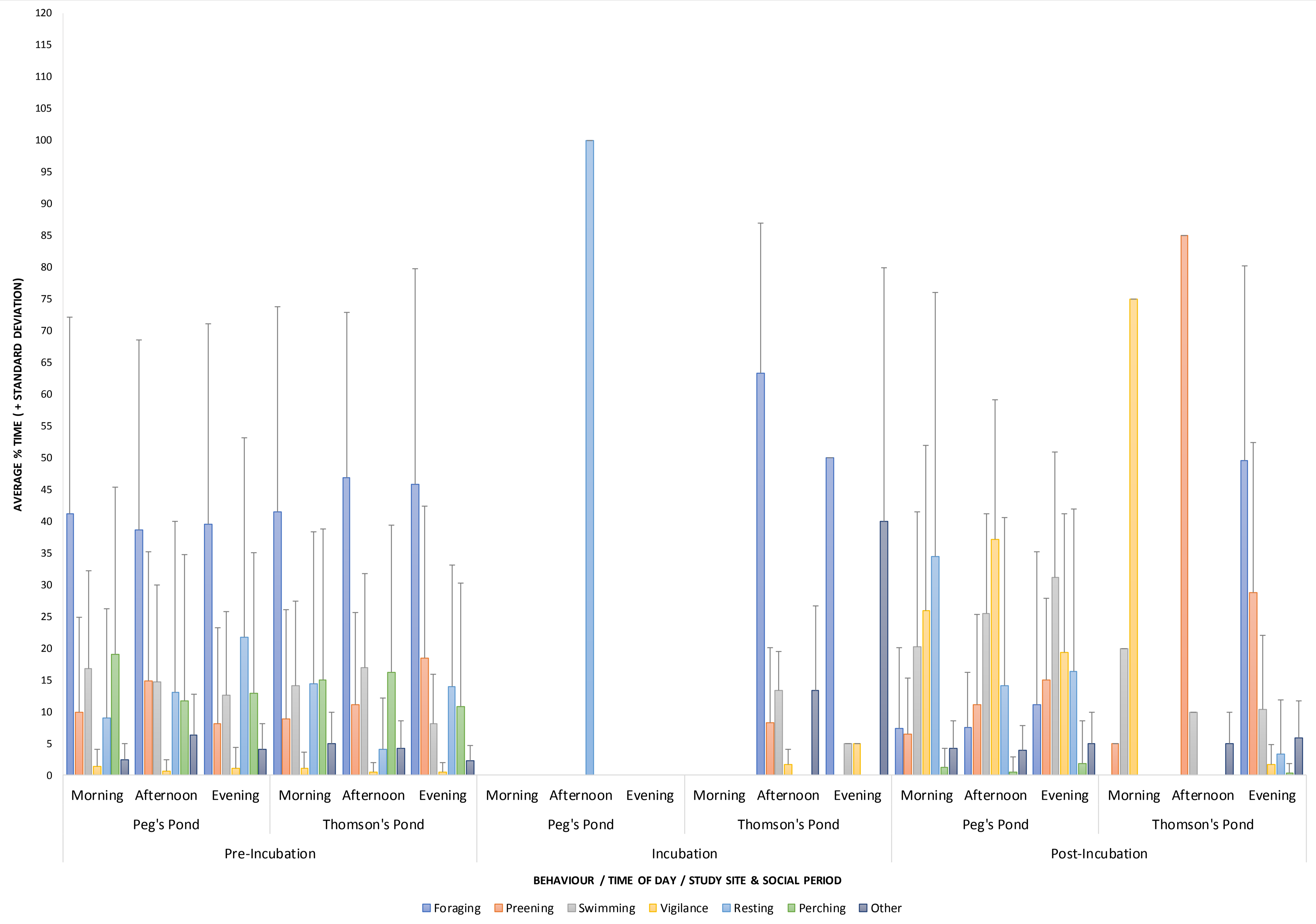

Figure 15. Average Time Budget (%) of the Female Mandarin Duck at Different Times of The Day, at Both Study Sites and During Different Social Periods.

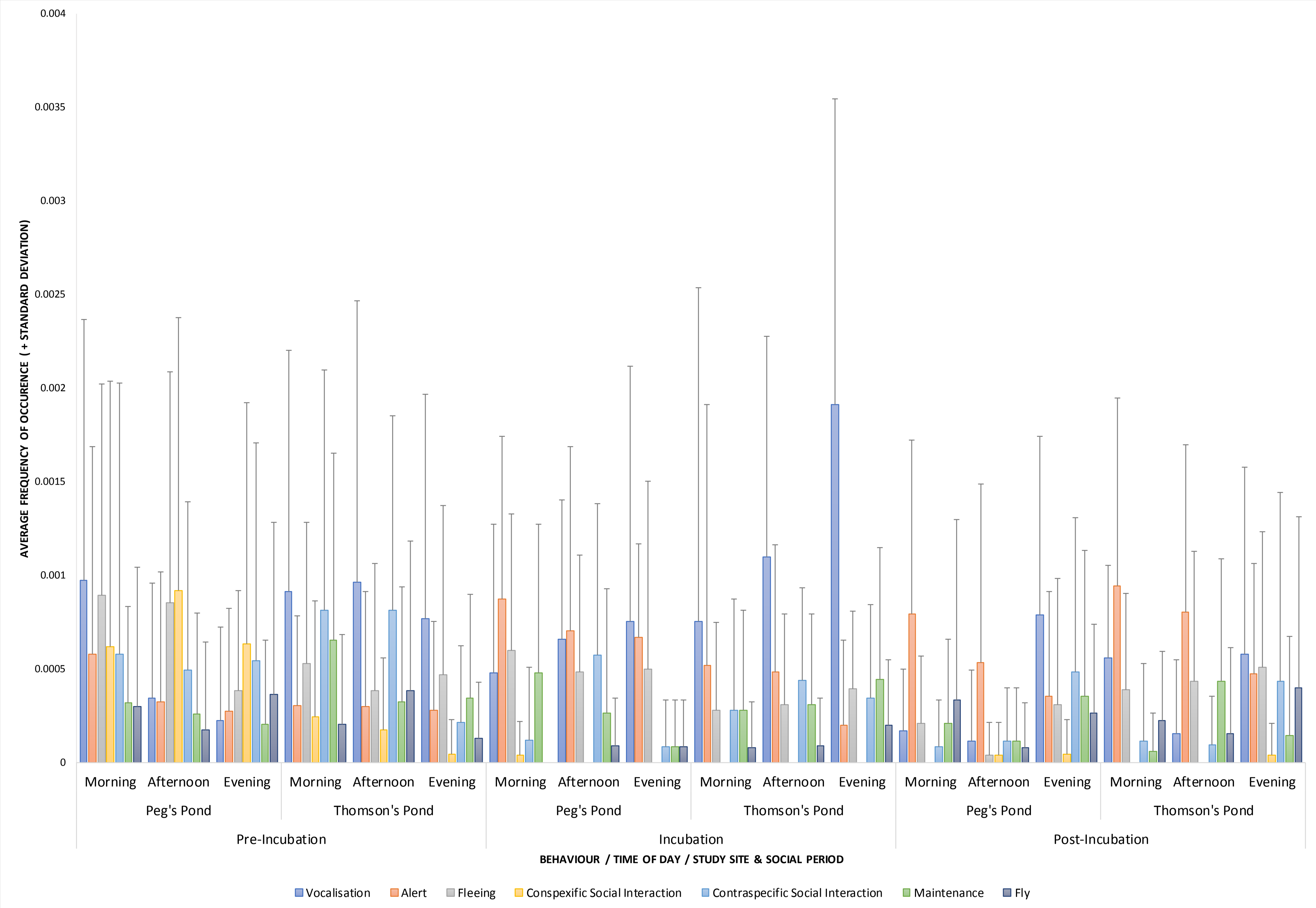

Figure 16. Average Frequency of Occurrence of the Male Mandarin Duck at Different Times of The Day, at Both Study Sites and During Different Social Periods.

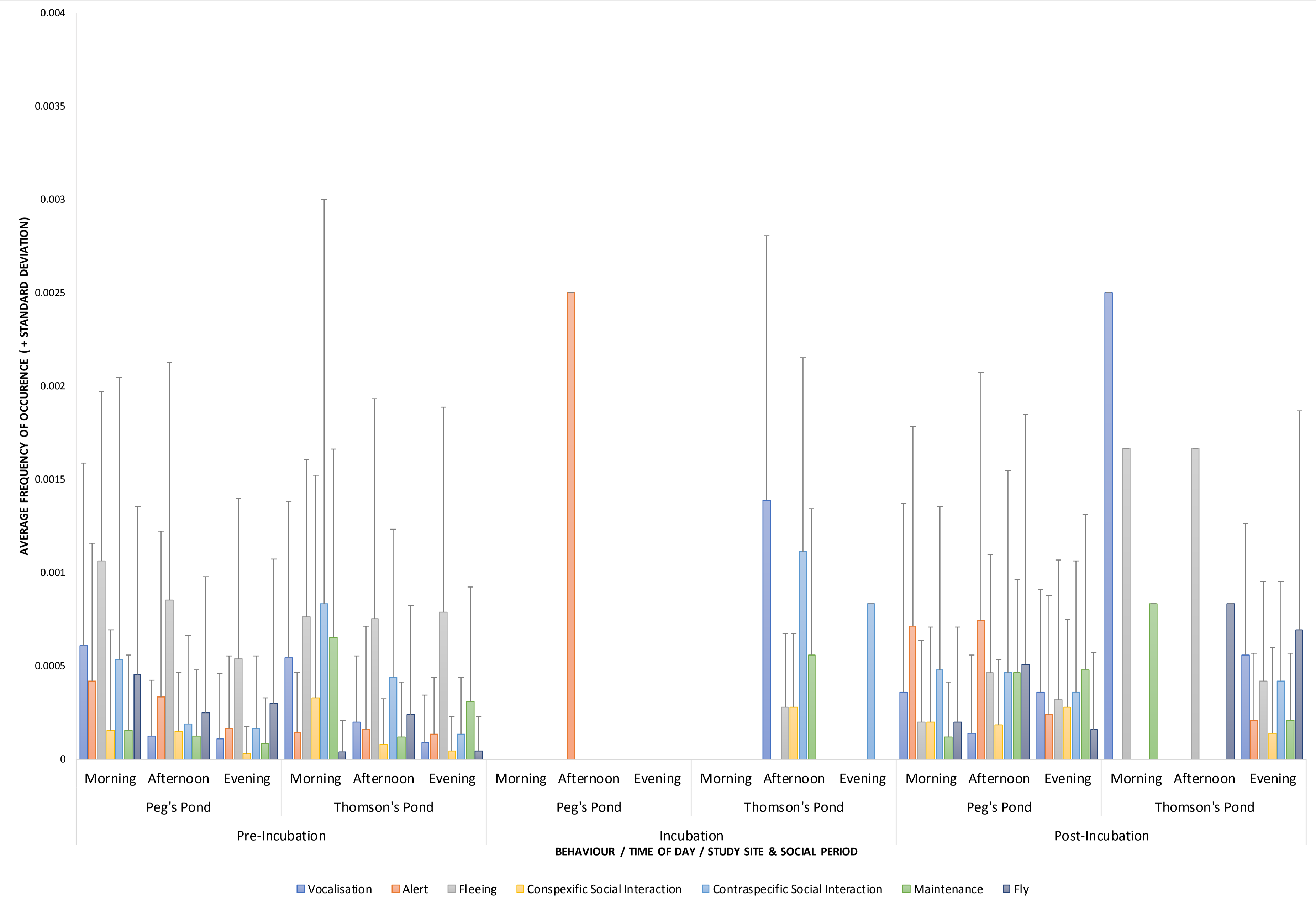

Figure 17. Average Frequency of Occurrence of the Female Mandarin Duck at Different Times of The Day, at Both Study Sites and During Different Social Periods.